Singapore, 18 May 2005

Current IntelliSys projects

*Development of Intelligent Control Systems Technology for Systems with Fast Dynamics (Principal Investigator: A/P Er Meng Joo)*

This research is concerned with the development of intelligent control systems technology for systems with fast dynamics. In the area of flight control, many modern control strategies have been employed for high control performance over a broad operating envelope. Gain-scheduled controllers are traditionally designed on the basis of the dynamics relative to a family of trim conditions assuming that the airspeed is slowly varying. However, during aggressive manoeuvring, the vehicle may be far from equilibrium with rapidly varying airspeed. In addition, the requirements to operate at high angles of attack necessitate scheduling on rapidly varying quantities such as the instantaneous incidence angle rather than, for example, conventional flap scheduling on averaged incidence. It should be highlighted that scheduling on instantaneous incidence is well known to lead to instability and is invariably avoided in classical scheduling arrangements. Also, it may be difficult to determine the operating regimes, and how they should be characterised, which is the key to successful modelling and control using these methods.

In recent years, much research effort has been directed towards design of intelligent controllers to handle structure and/or unstructured uncertainties for systems with fast dynamics using fuzzy logic and neural networks. Unfortunately, robustness and reliability have not been fully addressed. Moreover, to our knowledge, the controller is rather complicated and is not suitable for real-time applications. The objective of this research to develop intelligent control systems technology suitable for systems with fast dynamics. The developed technology will be employed to control a Vertical Take-Off and Landing (VTOL) mini Unmanned Aerial Vehicle (UAV), an Autonomous Unmanned Guided Vehicle (AUGV), an indoor mobile robot and a humanoid robot. So far, three learning algorithms for intelligent control of uncertain nonlinear systems have been
developed. The three algorithms are Generalized Dynamic Fuzzy Neural Networks (GDFNN) learning algorithm, Dynamic Fuzzy Q-Learning (DFQL) learning algorithm and Fuzzy Logic-Based Iterative Learning Control algorithm.

The GDFNN learning algorithm is an on-line self-organizing learning algorithm. The salient feature of the algorithm is that a priori partitioning of the input space and selection of initial parameters are not required. Moreover, an on-line allocation method of ellipsoidal basis function parameters is developed to avoid random choice based on fuzzy $\varepsilon$-completeness. The proposed GDFNN has faster learning speed instead of iterative learning. Experimental results in the wall-following task of mobile robots clearly show the superiority of the GDFNN-based approach.

The DFQL learning algorithm is a kind of Reinforcement Learning scheme suitable for learning in completely unknown environments. The proposed DFQL is capable of tuning fuzzy inference systems online. The salient feature of the DFQL is its on-line self-organizing capability and structure and parameter identification are carried out automatically and simultaneously. Experimental results in the goal seeking task of mobile robots demonstrate the effectiveness of the proposed learning approach.

The FLILC is proposed for uncertain nonlinear systems with repeatable control processes and control tasks. In the developed learning scheme, fuzzy logic is employed as an approximator to generalize the relationship between system initial states and control inputs via conducting a repeatable control task from different starting points. The then-parts of the fuzzy rules are updated iteratively based on the initial state, the system input and the tracking error of previous learning iteration. Simulation results demonstrate the superiority of the proposed learning algorithm.

An Integrated Software Environment for Algorithms Development – A Platform for Problem Solving and Engineering Design Optimisation (Principal Investigator: A/P Lim Meng Hiot)

The primary focus of our research is to develop a computational platform that serves as a software environment for developer of systems for solving complex engineering problems. Such an environment should encompass a complete view of the resources available. It provides a realisation of both the hardware (machines, memory, locations, speed, etc) and software (methodologies, software objects, design interface, etc) resources at the disposal of the system developer. Through this research, we seek to demonstrate the effectiveness of the problem-solving environment by developing a solution methodology of a real world problem. The application is one of real-time dynamic path planning for unmanned aerial vehicles.

FPGA-Based Development of Dynamically Reconfigurable Nodes for Distributed Networks of Multisensor Devices (Principal Investigator: A/P Andrzej Sluzek)

Adequate sensing capabilities are the key issue in systems working autonomously (or semi-autonomously) in unstructured, unfamiliar environments. Networks of sensing devices are one of the emerging technologies for providing such systems with information about status and conditions in a large fragment of the environment. In such networks, a huge amount of sensed data that should be acquired and processed in real time requires both hardware-implemented (or hardware-supported) processing algorithms and intelligent data selection mechanisms (to prevent informational saturation). The main objective of this project is to improve functionality of
networks of sensing devices by incorporating FPGA technologies (and prospectively other similar techniques). FPGA-based solutions can potentially combine advantages of both hardware implementations (small size, optimised timing, high level of parallelism, lower power requirements, etc.) and software approach (flexibility, numerous alternative algorithms, etc.).

A.I.-based Simulation (Principal Investigator: A/P Narendra Shivaji Chaudhari, co-Principal Investigator: A/P Er Meng Joo)

The objective of this research is to explore novel methods in machine learning that can enhance artificial intelligence in simulation and computer games. The eventual aim is to generate and deploy such a form of artificial intelligence in common combat or melee applications where users can be exposed to opponents/non-player entities that adaptively learn and thereby challenge their minds. This research will focus on machine learning that is realistic, robust, and efficient for both strategic and real-time applications. We plan to investigate the usage of machine learning techniques such as, grammatical learning, neural networks, reinforcement learning, evolutionary learning, etc., for their suitability in simulation and games. In many situations, these techniques require an inconveniently large number of observations; for specific simulation scenarios, further modelling is needed to use them efficiently. This gives rise to a collection of research issues regarding the different levels of applicability of these techniques in simulation environments. Specific simulation and game scenarios that we consider for this research include combat tactics such as attack, defense and weapon/resource selection upon melee encounters. We focus on machine learning methods that can acquire, retain and apply domain knowledge.

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